9+ YEARS OF DISPOSAL EXPERIENCE AT THE WASTE ISOLATION PILOT PLANT (WIPP)

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Abstract

WIPP disposes of contact-handled waste since 1999 and remotely-handled waste since 2007. Emplacement methods range from stacking 0.21- 4.5 m^3 containers inside rooms to remotely inserting 0.89 m^3 casks into horizontally drilled holes. One-third of WIPP's authorized repository capacity is full. Neither employees nor the public have been exposed to radiation beyond local background variability. Waste characterization, transportation, and disposal consistently meet or exceed safety standards and expectations. Process improvements continuously reduce cycle times and costs. Beyond current political, regulatory, and administrative restrictions, WIPP helps pave the way toward permanent isolation of all radioactive waste categories, including high-level.

1 Current Repository Operations

The Waste Isolation Pilot Plant (WIPP) east of Carlsbad, New Mexico, has since March 26, 1999, been disposing of radioactive waste in impermeable bedded Permian salt 655 m below the surface. This weapons program waste is considered intermediate-level in an international context, but in the U.S. it is categorized as transuranic (TRU) waste. The repository is currently authorized to eventually accommodate ~175,000 m^3 of radioactively contaminated, solid, non-heat generating, and mostly unconditioned laboratory and manufacturing trash. About 12 t plutonium, in addition to other radioactive isotopes, are estimated to eventually be isolated inside WIPP.

The US Department of Energy (DOE) did, and continues to, excavate and operate WIPP specifically and almost exclusively for waste disposal. Illustrations on just about any aspect of WIPP operations are readily available at the WIPP web site (US DOE, 2008a) and the DOE photo archive web site (US DOE, 2008b). Location- and design-specific salt creep rates are relatively high (4-6 cm/yr), leading to rapid waste encapsulation and permanent isolation.

1.1 Contact-Handled Waste

Most contact handled (CH) TRU waste is contained in seven-packs of 0.208 m^3 drums or in single 1.88 m^3 standard waste boxes (SWBs). Other approved CH waste containers include four-packs of 0.32 m^3 drums, three-packs of 0.38 m^3 drums, and single 4.5 m^3 ten-drum-overpacks (TDOPs). Waste containers are stacked inside disposal rooms, and each stack is capped by a bag of pelletized MgO. CH waste containers may have surface dose rates up to 0.002 Sv/h. Under the current regulatory regime, waste resulting in dose rates at the surface of the container in excess of 0.002 Sv/h must be packaged in remotely handled canisters and disposed of as described below.

1.2 Chemical Backfill

WIPP salt is hydrologically quite stable: no groundwater intruded since its original deposition >250 million years ago; however, for purposes of evaluating future repository performance, it is assumed that water may some day inundate the disposal rooms due to inadvertent human intrusion. For this reason, a chemical backfill (MgO) is emplaced along with the waste to buffer the pH of the assumed resulting brine and to reduce actinide solubility. MgO would also consume essentially all the CO2 that could be produced by microbial activity assuming all cellulosic, plastic, and rubber (CPR) materials in the TRU waste and its containers participated in the reactions. MgO is emplaced in polypropylene “supersacks” (each weighing ~1,900 kg) on top of the freestanding container stacks. Creep closure of WIPP disposal rooms will rupture the supersacks, crush and compact the waste containers, and in the process disperse the MgO. The dispersed MgO will be exposed to the room atmosphere, to any CO2 produced by microbial consumption of CPR materials, and to H2O vapor and any brine present. More details on the very conservative but regulation-required release scenarios leading to the emplacement of MgO are available in the WIPP Compliance Certification (US DOE, 1996) and Recertification Applications (US DOE, 2004).

1.3 Remotely-Handled Waste

Remotely-handled (RH) TRU canisters with a volume of 0.89 m^3 (length 3.07 m, diameter 0.66 m) and a maximum weight of 3.63 tons arrive and are handled in shielded re-usable casks before they are emplaced in pre-drilled horizontal holes (in the walls of the disposal rooms), which are then closed with concrete shield plugs. Current emplacement practice, while successful so far, includes serial single-failure points subject to future process improvements. RH waste containers may have surface dose rates up to 10 Sv/h.

1.4 Operational Challenges and Lessons

Examples of obstacles overcome and lessons learned during the first 9+ years of disposal operations include:

1.4.1 Excavation Stability

Relatively high rates of excavation closure due to salt creep cause rapid isolation of the waste in the impermeable surrounding salt. Excavation of the first panel of seven rooms was completed by 1988 in anticipation of first waste receipt. But political, regulatory, administrative, and judicial hurdles delayed arrival of the first shipment for another eleven years. Meanwhile, salt creep, brittle deformation of anhydrite layers in the back and floor, and fracture development in the disturbed rock zone around excavations continued. The gradual decline in excavation stability required costly countervailing measures, e.g., pattern bolting and re-cutting many excavations, to maintain a safe working environment and clearances sufficient to accommodate waste handling equipment. With the benefit of hindsight, delaying excavation to full design dimensions of access drifts and the first panel until all hurdles were cleared would have been preferable.

1.4.2 Salt Hoist Capacity

Driven by the desire for expedited clean up of waste generator sites to achieve protection of neighbouring communities sooner than originally intended, the DOE decided early in the operating life of WIPP to accelerate disposal rates beyond those anticipated in designing the facility. Speeding up the mining rate was fairly simple, but the resulting flow of mined salt exceeded the hoisting capacity of the salt shaft. The solution was to mine during one shift, stockpile the excess salt underground, and hoist it to the surface during a second shift. Double-handling of some of the mined salt increased cost and occupational risk at WIPP, but achieved the purpose of more rapid risk reduction at some generator sites. The lesson here is to design key components of repositories as robust and flexible as possible to accommodate moderate changes without creating bottlenecks.

1.4.3 Disposal Horizon Change

Geotechnical data and modelling after the first panel had been filled indicated that raising the WIPP repository level (floor and roof) by about 2 m should improve roof stability and reduce ground control needs. The regulator approved the proposal for implementing the change, beginning with Panel 3. Unfortunately, results did not match expectations, and actual ground control costs, primarily for additional bolting, increased. The 25+ year WIPP record of gathering and interpreting data from instrumentation and observation is impressively extensive, yet its length pales in comparison with the practical experience of salt and potash mines. Most of them have been in operation many decades, some even longer than a century. Other repositories in similar geologic settings but with long mining histories have not reported surprises such as WIPP encountered as the result of the horizon change. This contrasting experience encourages a re-assessment of the commonly held but largely unexamined assumption that prefers de novo excavations over former or current mines, in which to locate repositories.

1.4.4 Waste Retrieval

A records check in 2007 revealed that a waste drum already emplaced in Panel 4 contained less than a cup full of free liquid, which is prohibited by the WIPP waste acceptance criteria. When the problem was discovered, 36 rows of waste containers had already been placed in front of the offending "errant" drum over-packed inside an SWB, turning retrieval into quite an operational challenge. Analysis showed beyond rational doubt that leaving the drum in place was less risky than all retrieval options. The US Environmental Protection Agency (EPA), the chief regulator of WIPP with focus on the radiologically toxic waste constituents, raised no objection to leaving the drum underground. But the New Mexico government agency regulating the chemically toxic constituents of the waste ordered the drum to be retrieved and returned to the generator site anyway. This decision flew in the face of an unchallenged independent evaluation that "the radiological risks (sic) from WIPP wastes are much greater than the risks from hazardous wastes"(Channel, Neill, 1999). WIPP employees accomplished actual retrieval of the errant drum quickly and accident-free, but at considerable risk as well as expense in time and money. The experience highlights the need to critically examine regulatory regimes guided by rote rulebook compliance rather than thoughtful case-by-case comparative risk assessment.

2 Continuing Process Improvements

As part of its drive to constantly increase operational safety and efficiency, WIPP's continuing process improvement goals focus on decreasing vulnerabilities by reducing, eliminating, or optimizing requirements that do not enhance safety or add value. As the result of past efforts, cycle time for processing a CH waste shipment has been reduced from eight to less than two hours, and RH shipments have ramped up from one to six per week. Current and future efforts include:

2.1 Simplify Panel Closures

The two access (intake and exhaust) drifts to each panel are closed after the panel has been filled with waste. Closure structures are designed to protect workers while disposal operations in other panels continue. The original WIPP permit requires the eventual emplacement of a massive concrete monolith in each drift. During pilot-scale test pours, this design proved very difficult and expensive. Thus, the first three panels were -with permission of the regulators- closed with simpler systems. Structures installed in the access drifts of Panels 1 and 2 consist of solid concrete block walls without penetrations for monitoring conditions behind the walls. The Panel 3 structures consist of a much less expensive combination of chain link fence, brattice cloth, and piled-up mined salt and incorporate conduits for remotely monitoring geotechnical instruments and the atmosphere inside the panel. WIPP expects to propose to the regulatory agencies simple run-of-mine salt barriers about 30m long and backfilled from floor to back. Such barriers should be adequate after re-consolidation by creep to effectively isolate disposal panels from each other. Data gathered through the penetrations in the closure structures in Panel 3 and panels to be closed in the future will help the regulator evaluate and approve a safe yet cost-effective final design choice.

2.2 Re-configure Some RH Waste as CH Waste

Operating experience gained since first receipt of RH waste has made obvious the need for alternatives to eliminate or at least alleviate the many single failure points contained in the RH waste handling sequence. Current practice involves several components without backup, substitute, or spare; many of them were custom-built ~25 years ago. An alternative already being discussed and likely to be presented to the regulators in the future would be to load at the generator sites materials that would otherwise be categorizes as RH waste into shielded containers that could then be handled and disposed of alongside CH waste, i.e., stacked vertically inside rooms. WIPP considers proposing that the waste packaged in this fashion would still be counted against the RH waste capacity limit imposed by regulations and agreements with the state of New Mexico. This method could be applied to a significant fraction but not all RH waste. The remainder would continue to be emplaced into horizontal holes.

2.3 Reduce or even Eliminate Chemical Backfill

The head of the (now defunct) Environmental Evaluation Group (EEG), an independent and frequently very confrontational oversight body, used to call the requirement for MgO as chemical backfill and engineered barrier a prime example of the “belt-and-suspenders” approach to many aspects of WIPP. The assumptions underlying, and the rationale for, adding MgO to the repository environment are subjective, very conservative, and in some cases unrealistic. The prospect of potential savings during the life of WIPP, resulting from the reduction or even removal of this requirement, is in the range of several tens of millions of dollars. In addition, substantial CH waste emplacement efficiencies may result from changing this requirement. Discussions between WIPP and the EPA on this topic are continuing.

3 Science Underground

The DOE offers WIPP underground real estate not needed for waste disposal to researchers from around the world as a laboratory to study a variety of subjects. The underground environment is very suitable for experiments in many disciplines, including particle astrophysics, waste repository science, mining technology, low radiation dose exposure effects, fissile materials accountability and transparency, and deep geophysics. Research unrelated to waste disposal is accommodated as long as it has no negative impact on the primary waste isolation mission.

3.1 Applied Repository Science

Being the world's first fully licensed deep geologic repository for TRU waste, WIPP can serve as a test bed for enhancing the concepts and designs of future geological repositories for other permanent disposal programs in at least two areas:

3.1.1 Repository Performance

WIPP demonstrated compliance with regulatory standards initially in 1998, and again for the first re-certification in 2004. Features, events, and processes that may affect the integrity of the site for the next 10 000 years must continue to be re-assessed by probabilistic analyses. A performance assessment system consisting of conceptual models, computational codes, parameter databases, and computer systems is being maintained and constantly updated to support future re-certification applications and analyses of contemplated changes to the disposal system.

3.1.2 Transparency

The DOE has made WIPP available to serve as a proving ground of techniques to answer two questions for the back-end of the nuclear fuel cycle, namely disposal: First, how do we establish to someone else’s satisfaction that our nuclear activities pose no threat, either by accident or proliferation? Second, how do we establish to our own satisfaction that someone else’s nuclear activities pose no threat? A successful transparency program can monitor remotely the geologic disposal of radioactive waste without adversely affecting repository operations or regulatory compliance. WIPP has served as a host for evaluating non-proliferation technologies in a deep geologic repository. Monitoring experiments demonstrated the value of a transparency test bed at WIPP. Preliminary results were reported at the International Conference on Geologic Repositories in Denver in November 1999.

3.2 Basic Science

WIPP may be the best and most cost effective location in the US to serve as an underground laboratory dedicated to experiments to probe the nature of the cosmos, to study known particles and their interactions, and to search for postulated particles that are thought to pervade our universe. A clear advantage of exploiting an existing facility, especially one that is already operated by the government, is to make best use of taxpayer’s investment with highest scientific return. There has already been a large investment to support science in WIPP. Neutral current detectors that helped the Sudbury Neutrino Observatory to confirm that neutrinos have mass were first tested in the WIPP underground. Currently active experiments support the search for neutrino-less double-beta decay which, if proven to exist, could change our understanding of the universe.

3.2.1 Low-Background Environment

Nuclear and particle physics communities need suitable facilities in which to survey samples of materials for radiological impurities at unprecedented sensitivity. WIPP offers very low background radiation and excellent shielding from cosmic radiation. Augmenting the shielding against cosmogenic radiation provided by the overburden, WIPP salt contains significantly less natural radioactivity than rocks exposed in most other underground mines. Careful monitoring to document clean waste disposal operations ensures that hardly any airborne radioactivity, e.g., radon, contributes to instrument background levels.

There is also a growing need to create detector components underground to avoid incorporation of cosmogenic impurities. This includes underground storage of detector or shielding materials needed later at either WIPP or other location. Small quantities of lead bricks and other shielding materials have been stored in the WIPP underground for many years. A low-level counting chamber made of pre-WW II steel is available, and most recently some radio-pure copper test parts were electro-formed in the WIPP underground, demonstrating the complete elimination of radiogenic elements in materials used for detector construction

A third category of research can use the low radiation background in the WIPP underground to investigate the biological effects of low-level radiation. An international summit in January 2006 concluded that WIPP fulfills the requirements for such an underground laboratory. It also proposed an experimental design that would conclusively test the linear no-threshold hypothesis of dose response to low dose and low dose rate radiation (Orion International Technologies, 2006).

3.3 Science Benefits to Repository Operations (What's in it for DOE and WIPP?)

Conducting sensitive underground experiments during the disposal of radioactive waste supports the argument for safe and sound repository operation. Delicate research at WIPP provides a counterpoint to the mistaken perception that the project is nothing more than a radioactive waste "dump". While supporting experiments, WIPP also gains expertise and experience in handling exotic materials and equipment configurations. Research grants and experiments create jobs in the private sector and boost the regional economy. The science mission helps recruit, retain, and develop talent in SE New Mexico. Taxpayers benefit from science at WIPP because it optimizes the return on their investment. Finally, the subtle irony of using the low-background radiation environment for basic science research right next to mega-curies of radioactive waste is not lost on the public. The message received is that radioactive waste may not be as fearsome as represented by anti-nuclear activists.

4 Opportunities for Cooperation

More than 35 years of WIPP history, including almost ten years of practical waste disposal experience, constitute a significant record in the field of deep geologic waste isolation. WIPP participants have shared this record by organizing and hosting symposia and workshops and by participating in international waste management organizations and conferences. Beyond these past efforts, much more can and should be done to share scientific and technical expertise and experience that enhance operational and post-closure assurance, safety, and reliability for all repositories.

4.1 Actual Repository Performance

WIPP is one of only three operating underground repositories (the other two being the Swedish and Finnish facilities for low- to intermediate-level waste) that were excavated primarily for waste disposal. Lessons derived from any aspects of the performance of these excavations, but especially from phenomena that were not anticipated, may help other repositories that do not have the benefit of decades-long mining histories. The rich performance experience of repositories for chemically toxic waste in former or currently active mines in bedded salt can in turn benefit current and future repositories for radiologically toxic waste in similar host rocks.

4.2 Waste Retrieval

Retrievability is a bit of an oxymoron in the context of permanent isolation. But depending on the repository environment and the timing of a retrieval decision, it can be technically possible. At least one repository for chemically toxic waste has retrieved wastes for which uses were found after disposal, and WIPP retrieved an “errant” drum that was found to be not in compliance with regulatory proscriptions. In the former case, the window for retrieval is many decades wide, because room closure rates are so low they cannot be measured past the first decade after excavation. In the latter case, retrieval even just a few months or a year later would have been indefensibly difficult, risky, and expensive. In any case, lessons drawn from actual retrieval experience may be helpful to current and future repositories.

4.3 Public Acceptance

Underground waste repositories have enjoyed decades of successful operation in several countries [6]. Most relevant to the public acceptance of future repositories are those that were operated in open societies, with “the consent of the governed.” The German repositories for non-radioactive waste in salt and potash mines, the Scandinavian repositories for operating waste in granite, and WIPP can help each other and facilities in the planning or preparation stages achieve the same or even higher degree of acceptance and voluntary consent they were able to generate for themselves.

4.4 Transparency: Key to Success in Transportation

While opponents of anything radioactive used to consider waste transportation an easy target, the WIPP record has proven them wrong. TRU waste haul routes are established in early, close, and transparent cooperation with corridor communities and jurisdictions, foremost among them their transportation and emergency response authorities. WIPP gives these agencies real-time access to satellite tracking data for all shipments. Well before starting to use a transportation route, WIPP truck drivers introduce themselves and their tractors, trailers and transportation containers in “road show” displays at schools, malls, and town halls along the route. Students, teachers, community leaders, and the general public are invited to come, ask, and touch. Supportive attitudes are not taken for granted, thus communication continues even after operations have been going smoothly for many years. Constant communication makes it easy to monitor and fulfill all commitments and to avoid surprises.

5 Applications to High-Level Waste Disposal

While high-level waste (HLW) is neither permitted nor planned to be disposed of at WIPP, almost ten years of operating experience and quite a few data gathered during prior site investigations can be useful for future repositories in salt that may some day accept HLW.

5.1 Early WIPP Plans

The original WIPP concept actually included not just one but two disposal horizons: one for intermediate-level TRU waste, and a lower one for defense HLW. Planning for the second disposal level ceased during the early years of the project, but parts of the waste handling building, including a hot cell, had been designed and built to safely handle HLW just the same. Early rock mechanics testing included experiments with heated container configurations simulating HLW at emplacement thermal densities up to 18 W/m2. Data accumulated during these experiments should be useful to future repositories for heat-generating waste in salt.

5.2 Simulated HLW Tests

Original intentions contemplated tests with simulated and actual HLW, but eventually only experiments with simulated waste were actually conducted. Of special significance for heat-generating HLW were thermal/structural interactions tests. These tests investigated the stability of underground excavations during waste disposal and possible retrieval and the long-term deformation of excavations.

One unique configuration used a heated round pillar in the center of a round room. The creep of room and pillar was recorded at ambient temperature for one year, after which the pillar was covered with insulating blankets, heated to about 70ºC with strip heaters, and kept at that temperature for several more years. A one-year cool-down period concluded the ten-year experiment.

Interest in, and funding for, actual HLW experiments in salt waned after the U.S. Congress in 1987 chose to focus further HLW-repository site characterization on the Yucca Mountain Project. If that project falters, the concept of HLW disposal in rock salt may experience a renaissance in the U.S. and elsewhere.

5.3 Horizontal Emplacement Lessons

Alone among former and current underground repositories, WIPP is placing waste canisters in holes drilled horizontally into disposal room walls. Despite the significant potential for delays from serial failure points in the WIPP RH emplacement process, the project has managed to keep up with deliveries from generator sites. WIPP practice to date and future process improvements may shorten the learning curve for other waste management programs. The WIPP experience and initial calculations strongly indicate that a much more efficient and safe method than horizontal (or, for that matter, vertical) emplacement in drilled holes may be to simply lay canisters down along the ribs of disposal rooms and to cover them (about 3m deep) with run-of-mine salt at its natural angle of repose for shielding. If and when this and other improvement concepts mature, they will be shared with the international community.

5.4 RH-TRU Waste: Stepping Stone from L/ILW to HLW

WIPP takes no credit for the shielding drums and other containers provide to CH-TRU waste. The various container configurations are intended to confine the waste only while people are in close vicinity and to serve as barriers against release, inhalation, and ingestion. This corresponds to best management practices for containerized low-activity waste.

RH-TRU waste must be shielded while people are in close vicinity during storage, transportation, or disposal operation. It requires radiological precautions similar to HLW. But it differs from HLW in that it does not generate significant heat. RH-TRU waste occupies an intermediate position between L/ILW and HLW. Much that is learned at WIPP during RH operations is therefore of potential use to HLW disposal, whether in salt or other host rock

6 Conclusion –Integrated Multiple Underground Use

WIPP and its predecessors and contemporaries continue to varying degrees a trend toward a more comprehensive use of underground resources than used to be practiced in the past. Space originally excavated for one use alone is increasingly being made available for a variety of additional purposes, be they secure storage, e.g., Hutchinson and Kansas City, permanent disposal of dangerous wastes, or scientific experiments that need shielding against terrestrial and cosmogenic background radiation. Environmental and fiscal prudence mandate ever more integrated multiple use of underground space.

In an ideal future project, planning for underground mining of mineral resources incorporates from the beginning not just safe and efficient mining and eventual abandonment and reclamation but serious consideration of follow-on uses for the excavated space. It has now been proven quite feasible to start with mineral exploitation, continue by phasing in science experiments, and finish by filling some or all of the remaining space with waste before decommissioning the entire project. The Asse has accommodated all three of these phases; several German mines (mostly potash and salt) and WIPP are accommodating two, and the Bure underground research laboratory will quite possibly be used for basic science after it has served its primary purpose. Collaboration of these and other facilities promotes the more complete and sustainable use of natural and financial resources and serves mankind.

References:

Channell, J. K., and Neill, R.H, 1999. A Comparison of the Risks from the Hazardous Waste and Radioactive Waste Portions of the WIPP Inventory. Report EEG-72. Environmental Evaluation Group. Albuquerque.

Orion International Technologies, 2006. Ultra-Low Level Radiation Effects Summit, Carlsbad, NM, January 15-18, 2006, Final Report. Albuquerque.

Rempe, N.T., 2007. Permanent underground repositories for radioactive waste. Progress in Nuclear Energy 49 (365-374). Elsevier. London.

U.S. Department of Energy, 1996. Compliance Certification Application. http://www.wipp.energy.gov/library/CRA/BaselineTool/Documents/CCA%201996.htm (accessed March 18, 2008).

U.S. Department of Energy, 2004. Compliance Recertification Application. http://www.wipp.energy.gov/library/CRA/BaselineTool/Index/Chapters_Appendices.htm (accessed March 18, 2008).

U.S. Department of Energy, 2008a. Waste Isolation Pilot Plant. http://www.wipp.energy.gov/ (accessed March 18, 2008).

U.S. Department of Energy, 2008b. Digital Photo Archive. http://www.doedigitalarchive.doe.gov/ (accessed March 18, 2008).